Industry Perspective

Propulsion Controls and Diagnostics Workshop

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Areas In Need of Additional Controls Research

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- Improved Safety
  - Integrated Propulsion and Flight Controls
    - Fast response engine
    - Stall management → allows pushing engine response
    - Adaptive, Fault Accommodating Control
      (control authority trades between engine and flight controls)
- Fuel Efficient Flight
    - Optimized Descent – Next Gen ATM enabled
    - Delayed Flaps → Fast Response Engine
    - Distributed Controls
- Improved Engine Life
    - Mission Optimized Controls
- Quantify Benefits!

Fight Operations That Can Improve Fuel Use

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- **Benefits from NASA Flight Programs**

Program (A/C)	Control	Benefits observed in Flight Tests	Specific Data
HIDEC (F-15)	Active Stall Margin Logic, Inlet Integration Logic	Improvements in Excess Thrust (Thrust-Drag), Fuel Consumption and Engine Life	TSFC reduced by 16%, Range improvement of 8%-10.5%, Reduced turbine temperate to 80F (→ 10-15% increase in turbine life)
PSC (F-15)	Model-based control algorithm that adapts to engine variations (Kalman filter to estimate component deviations for a normal engine model)	Increased Thrust, Increased Engine Life.	15% thrust increase (refurbished engines), 9% thrust increase (degraded engines). Reduce turbine temperate by 60F.

- **Study authorized by the DOE, circa 1980.**

Airline Flight Procedures	Saving potential %		
OPTIMIZED DECENT PROCEDURES	2.5 to 3	~0	• PROFILE DESCENTS ARE AN ATTEMPT TO IMPLEMENT AN APPROXIMATION TO OPTIMAL DESCENTS
REDUCED / DELAYED FLAPS APPROACHES	1 to 2	UNKNOWN	• PARTIAL IMPLEMENTATION • DELAYED FLAPS CONSIDERED UNSAFE BY SOME • CAUSES ATC PROBLEMS WHEN MIXED WITH CONVENTIONAL APPROACHES

Delayed flaps possible if quick engine transient available

Ref. SAE Technical Paper 800766, Covey, Mascetti, Roessler, Bowles, "Past and Poential Near Term Fuel Saving in Commercial Aviation Through Modified Operational Strategies", May 1980.

Integrated Mission Management

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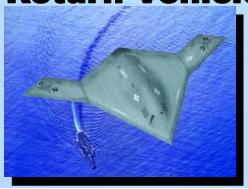
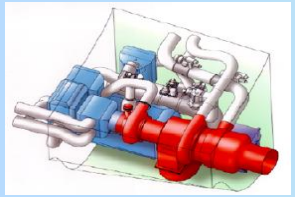
	Health Management	Adaptive Controls
Return Vehicle 	• Damage detection • Prioritized aircraft status and probability of return • Status to traffic control for return priority	• Damage Accommodation • Control reconfiguration • Threat avoidance • Maximum range (TSFC) • Alternate landing site selection
Complete Mission 	• Fault detection • Parameter estimation, e.g. drag, efficiency • Sensor source selection, e.g. sensor A, B or synthesized value	• Fault accommodation • Flight mode optimization e.g. sfc, life, performance • Model-based controls synthesizing engine/aircraft states
Mission Readiness 	• Fault detection • Prediction to next maintenance actions • Wiring interrogation • Mission readiness assessment	• Fault tolerant architecture allows mission initiation with existing faults • System retains redundancy even with pre-existing faults
Directed Maintenance 	• Maintenance scheduler • Maintenance prioritization • Directed maintenance actions • Integration with ground-based management systems	• Post maintenance reconfiguration of control algorithms

Mission Optimized Control is the enabler for the final levels of autonomy

Aircraft moving toward full autonomy e.g. Single Pilot Cockpit
Honeywell Has Both the Engine and Flight Controls Pieces of the Logic

Industry Assessment - Mission Optimized Controls

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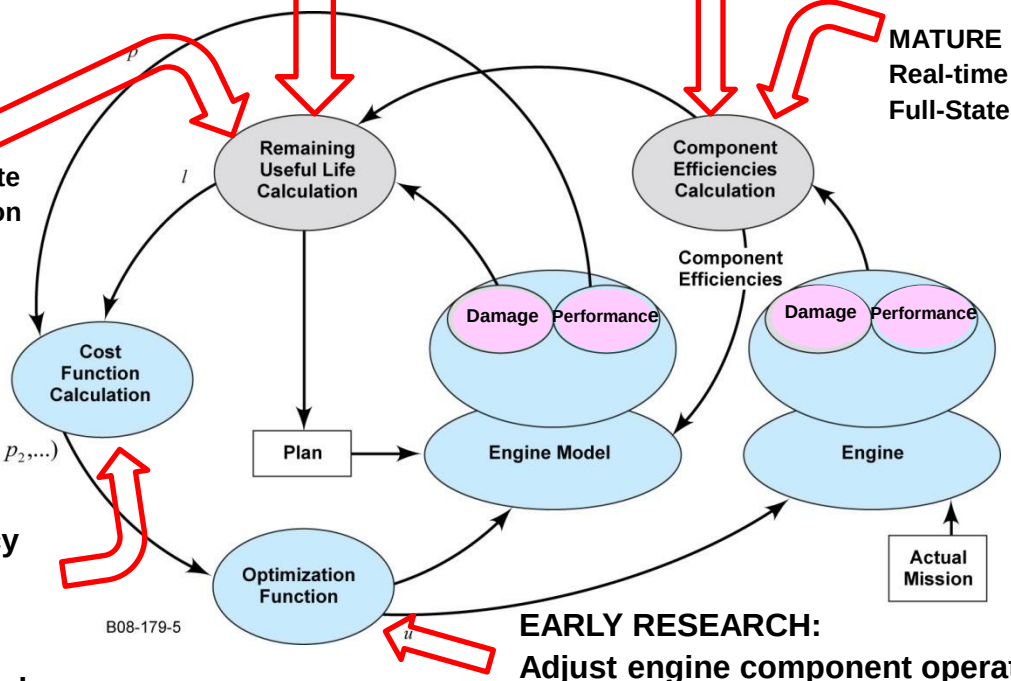
IN-PROGRESS
Real-time Fault Accommodation/ Mission Modification
Vehicle Level Health Assessment
Trajectory Regeneration

IN-PROGRESS
Engine Prognostics
Remaining Useful Life Est.

MATURE
Real-time Fault Accommodation
Full-State Engine Observer/Estimator

IN-PROGRESS
Real-time Engine Capability Estimate
Real-time Damage Effects Estimation



EARLY RESEARCH: $J = f(l_1, l_2, p_1, p_2, \ldots)$

Mission Objectives:

- **Maximize Cruise Efficiency**
- **Maximize Engine Life**
- **Maximize Performance**
- **Some combination of the above based on mission objectives**

EARLY RESEARCH:
Adjust engine component operating point based on mission objectives

Putting Together All the Pieces for Real-time Mission Management

Honeywell Experience w/ Integrated Flight/Propulsion

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- 20 + year history
- Flight Applications
  - MAV, OAV, RMAX, X-38 V132 & V131R
  - FAPI/X-31 (post stall, reduce tail size),
  - SMTD F-15 (thrust vectoring, thrust reversing)
  - CAPCS SR-71 (inlet unstart, airframe interaction),
  - DMICS F-16XL (multi-mode, tightly coupled)
- Hardware-in-the-loop, Piloted or Engineering Simulations
  - Lockheed Martin JSF VSTOL, F-18 HARV (post stall, high alpha), FAST, X-45/CMUS, OAV, F-117, YF-22, DC-X